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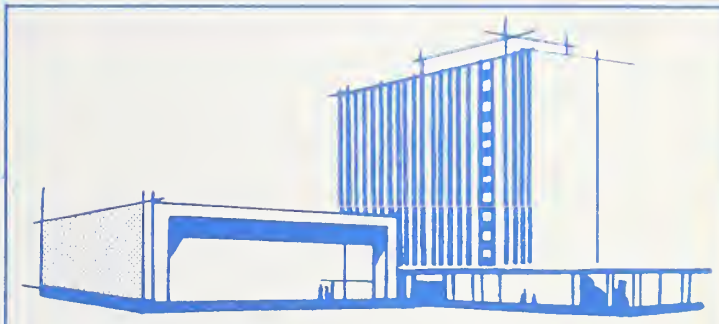

Windows and People: A Literature Survey

Psychological Reaction to Environments With and Without Windows

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Psychological Reaction to Environments With and Without Windows

Belinda Lowenhaupt Collins

Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

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Windows and People: A Literature Survey

Psychological Reaction to Environments With and Without Windows

Belinda Lowenhaupt Collins

Abstract

An understanding of human requirements for windows in buildings can be developed through a survey of the literature on the reaction to environments with and without windows. Evaluation of the response to a variety of windowless situations reveals that although the attitudes toward a windowless space are often somewhat unfavorable, the most adverse reaction occurs in a small, restricted and essentially static environment. This suggests that one function performed by a window is the addition of a dynamic, active quality to an interior environment. Consideration of the response to the actual presence of windows indicates that another essential function of a window is the provision of a view of the external world. Although almost any view is acceptable, there is some evidence that views with a high information content are preferable. In addition, windows admit illumination, in the form of daylight and sunshine which furnish a dynamic, changing character to a room. Yet, the functions of windows extend beyond view and illumination to an enhancement of the basic character of a room, such that the mere presence of a window may cause a room to appear more spacious. Finally, the optimum size and shape of a window for fulfilling these various functions is discussed.

Key Words: Daylight; fenestration; psychological; solar glass; spaciousness; sunshine; view; windowless; windows.

INTRODUCTION

The current need for energy conservation has forced some fundamental re-evaluation of building design. One aspect that has come under much review is that of building fenestration. Although windows provide daylight and ventilation, they also can allow undesirable heat gain and loss. In the past, the provision of light and fresh air were essential functions of windows. A building was uninhabitable without windows. Now however, these functions can be fulfilled by artificial lighting and mechanical ventilation. As a result, a number of people have suggested that a substantial reduction in the size of windows, or their complete elimination is desirable in order to reduce excessive energy consumption.

Nevertheless, even though a windowless building might be the best solution for eliminating energy loss through windows, there is considerable evidence that this may not be very desirable for the people in the building. A brief consideration of the role of windows in buildings suggests several tangible functions and benefits in addition to fresh air and lighting. Windows provide a view out, yielding some contact with the outside world. They also furnish first-hand knowledge of the weather, the time of day, and changing events in the external world. For some, they can supply relief from feelings of claustrophobia, monotony, or boredom. In a small room, they allow an opportunity for a change in focus, or a visual rest center. In addition, windows are used to lend character or beauty to a facade -- to break up the monotony of a featureless expanse of wall. Finally, they frequently furnish an indication of status or wealth. Executives sometimes occupy corner

offices with windows, while subordinates are placed in windowless, central offices. In fact, in England at one point, windows served as an indication of wealth, because of the "stiff" tax levied on each window. Only a rich man could afford to have many windows (Ferguson, 1968). The preceding list of suggested benefits and functions indicates that to limit the functions of windows to the provision of light and air would be erroneous.

Vehement assertions have been made about man's basic need for windows. Thus, Morgan (1967 p. 22) claimed that "ordinary man might therefore define the function of the window as the medium through which he maintains contact with his environment, with life, which enables him deep in his subconscious to know that he is a free man". Nevertheless, despite the prevalence of fervent assertions about man's "need" for windows, the fact remains that human requirements and preferences in building design have rarely been assessed in any systematic fashion. As a result, there is relatively little objective evidence on which to base a decision about the need for windows in buildings.

In an attempt to delineate some of the functions of windows, the literature on the reaction to both the presence and the absence of windows was surveyed. In the first section, the psychological reaction to windowless buildings is examined to determine if the absence of windows in a building exerts any noticeable effect upon the occupants' behavior or attitudes. In the second section, the various characteristics of windows are reviewed to define some of their functions and benefits.

This report is limited to coverage of the reaction of people within a building to the presence and absence of windows. It does not assess the impact of windows upon any sensory modality other than vision, but is confined instead to an investigation of the perceived need for windows in buildings.

SECTION I:

The Windowless Situation

Although totally windowless buildings are not particularly common, windowless rooms in the interior of buildings with windows are quite common. This situation occurs with great frequency in large urban office buildings, hospitals, schools, etc. It even occurs in residential dwellings in which rooms such as bathrooms or kitchens are located in the center of the building away from external walls. The totally windowless building is usually confined to a situation in which some specialized process occurs such as manufacturing or research. In these situations, noise, illumination, temperature and cleanliness must be strictly controlled, so that the elimination of windows is desirable. In other buildings such as schools, department stores, museums and theaters, windows may be deliberately eliminated in order to reduce outside distractions.

In each of these building types the reasons for not providing windows are different. Furthermore, the kind of activity performed in each of these buildings may vary widely. As a result, human reaction to windowless enclosures will be considered for different building types in separate sections.

Housing

The literature on reaction to windowless residential buildings is almost nonexistent. About the only review available is that of Hollister (1968) who conducted a widespread survey of all windowless building types for the Greater London Council. He mentioned, almost in passing, that a survey of residential buildings had found quite unfavorable reaction even to limited use of windowless bathrooms. This response was apparently so negative that he was led to conclude that "it seems most unlikely, however, that public opinion would ever countenance the use of windowless environments for habitable rooms in dwellings" (Hollister, 1968, p. 9). Evidently, architects and builders have felt that reaction to windowless homes would be so adverse that they have rarely attempted to build them. Whatever the reason, the literature on the reaction to other windowless situations, such as schools, is much more extensive and so will be considered in greater detail.

Windowless Schools

Reaction to the windowless school has been extensively investigated, partly because of the many conflicting claims and counterclaims about its benefits. Before discussing some of these discrepancies, it is important to understand some of the drawbacks to schools with windows.

Both in Britain and in the United States schools have frequently been primarily day-lighted, window-ventilated buildings, usually without air conditioning. In order to meet certain daylight standards, windows

have been made extremely large. This practice has resulted in serious problems of overheating and glare on warm, sunny days (Langdon and Loudon, 1970; Kay, 1963; Arnold, 1961). The use of daylight from side windows as the primary source of illumination has also resulted in an inflexible style of classroom arrangement (Nimnicht, 1966).

The drawbacks of excessive heat, glare, and inflexibility in classroom arrangement have made the controlled environment of the windowless school appear quite attractive to some educators and designers. The windowless school is seen as eliminating all these problems, while providing greater space for bulletin boards and bookcases, more even lighting levels, and freedom from outside noise and distractions (McDonald, 1961). Proponents of windowless schools claim that elimination of windows allows a classroom to be larger and deeper, with lower ceilings and reduced corridor spaces (Nimnicht, 1966). Such a change in school design can lead to a more compact yet flexible arrangement in which space for utilities can be reduced and usable classroom space increased (Brown and Hult, 1967). Another advantage of the windowless school design is the elimination of the costs and problems of excessive window breakage and similar vandalism (Brown and Hult, 1967). In summary, claims made for the practical and economic advantages of a mechanically-ventilated, artificially-lit windowless school are numerous.

In contrast, the disadvantages of the windowless school are viewed as primarily psychological. Many parents express deep reservations about confining their children in "windowless boxes" (Nimnicht, 1966). They argue that the experience of looking out the window can be, of itself, an educational experience, by providing the child with change, variety, and awareness of the external world (Burts, 1961; Perkins, 1966). Furthermore, the mere presence of windows is said to add a dimension of spaciousness to a cramped and crowded classroom (Burts, 1961).

It is difficult to weigh the economic advantages of the windowless school against its psychological disadvantages. Claims that the absence of windows will improve or impair student performance have been advanced with about equal frequency. Thus, it is alleged that students will learn better in a windowless classroom because it eliminates distractions. Yet, these same outside distractions are claimed to be a necessary adjunct to education, by providing relief from the monotony and confinement of the windowless classroom. It appears that the windowless school represents such a departure from traditional school architecture that many vehement opinions, both for and against it, have been advanced, usually without the benefit of any facts about student and teacher performance or reaction.

A number of studies have attempted to investigate the response of people to windowless schools. For the most part, these have been attitude surveys, dealing only with stated reaction to the windowless

school. Although scholastic performance might appear to be the most critical variable to consider when examining the effects of windowless schools, relatively few studies have examined performance. Two studies conducted in the early 1960's did assess the impact of window absence upon the scholastic performance, as well as the physical health, mental health, and academic aptitude of elementary school pupils. These studies also determined both teacher and pupil attitudes toward the windowless classroom.

Impact of the Windowless Classroom Upon Academic Performance

Demos, and various associates (1965, 1967), conducted a study of the effects of a windowless classroom in California upon fifth grade students and their teachers by comparing students in two classrooms, one with windows and one without. Numerous measures relating to academic performance, physical health and classroom behavior were examined during the two-year study. Pupil opinion toward the classroom was solicited by means of questionnaires.

Demos' examination of various achievement tests, grade-point averages, personality tests, and school health records revealed no significant differences between students in the two classrooms during the course of the study. As a result, he maintained that the ability to achieve academically and function intellectually was neither impaired nor improved by the windowless classroom.

The results of the examination of both pupil and teacher attitudes toward the windowless classroom did reveal some charges attributable to the lack of windows.

When pupil attitudes were surveyed, the windowless group expressed more favorable opinions about the classroom, school subjects and their teachers, as well as a greater feeling of well-being than the group with windows. When asked their opinion more specifically about the lack of windows, they were somewhat less positive. In the first year of the study, the students stated that they preferred the windowless classroom. In the second year, however, the students expressed a definite dislike of the windowless classroom. The authors did not discuss the reasons for the change in attitudes toward the windowless classroom during the two-year study. When questioned about the reasons for their preferences, the students who preferred the windowless classroom stated that they liked the absence of external, distracting stimuli. Those students who disliked the windowless classroom complained about the inability to see the sun, or have sunlight in the classroom.

The teachers were questioned both about their own attitudes and about those of the pupils. They expressed no particular preference for either classroom setting, although they felt that fewer distractions occurred in the windowless classroom. They also liked the increased wall space for bulletin and chalk boards, as well as the greater ease in darkening the room for films. Among the drawbacks to the windowless classroom were some feelings of claustrophobia, mechanical difficulties with the ventilation system, and the inability to grow plants.

The teachers were less enthusiastic about their students' response to the windowless classroom, even though the students had expressed reasonably favorable attitudes. The teachers claimed that the students in the windowless classroom had less interest in extraneous stimuli, evinced more hesitant and cautious behavior patterns and were more inclined to complain than the students with windows. It is not clear why there was disagreement between teachers and students about student behavior and satisfaction. Although the teachers also claimed that the students had better concentration and study habits in the windowless classroom, their claim appears questionable because there was no improvement in academic achievement.

Although Demos found that use of a windowless classroom did not alter scholastic achievement, he did find some hint of impairment in student behavior in the classroom. Furthermore, about half the students questioned did not like the windowless classroom. Nevertheless, Demos concluded that, because there was no change in academic performance or physical health, there should be no problem with placing elementary school children in windowless classrooms.

Another study of the effects of windowless classrooms was conducted with elementary school children by the University of Michigan Architectural Research Laboratory under the guidance of C. T. Larson in 1965. Unlike the California study, however, an entire school containing four separate grades was studied over a three-year period, so that all the windows could be removed from the entire school for a year. In this way the performance of the same students could be studied both with and without windows.

In the Michigan school study (Hoover School Study) Larson et al. evaluated scholastic performance, classroom behavior, and attitudes but not the physical or mental health of the children. As in Demos' study, the removal of windows did not appear to alter scholastic performance in any significant fashion. The only change was a reduced number of children in all grades who performed above average, although there was no increase in the number performing below average. When individual student performance was examined, however, it was obvious that some students performed better with windows and others performed better without. The authors concluded that random yearly variations in ability and motivation were responsible for the differences in performance rather than architectural design. When the overall absenteeism was examined, there were no significant changes from the condition with windows to that without. However, a grade by grade analysis revealed that kindergarteners were more frequently absent from the windowless classroom.

Larson et al. assessed student attitudes toward the windowless classroom by having the teachers question the students individually about their reaction to school. The teachers reported that the children did not comment spontaneously on the absence of windows. Yet, the teachers did indicate that when the children were directly questioned about the presence of windows in the classroom, the pupils expressed some desire for windows. Because almost 90% of the kindergarteners and only about 50% of the third graders expressed a desire for windows, the authors suggested that the desire for windows in the classroom declines with increasing school age and a more strictly academic

curriculum. Because the teachers were not trained interviewers, the discussion of attitudes toward windowless classrooms should be reviewed with some caution.

Adult reaction to the windowless classroom was varied in Larson's study. Parental attitudes did not change -- those that had not expected to like the windowless classrooms, did not; those that had, did. On the other hand, the teachers expressed quite favorable opinions: they liked the greater wall space and the removal of outside distraction. Perhaps the greatest index to their liking of the situation was the large number of complaints when the windows were reinstated. The teachers complained that the children were much more distractable, there was less bulletin board space and fewer bookshelves, the children could look out the windows too easily, the classrooms were stuffy and poorly ventilated, and there were excessive swings in temperature. As the teachers had not initially expected to like the windowless classroom, this unexpected shift of their attitudes was regarded by the authors as an indicator of the desirability of using windowless schools.

As the authors put it: "The one positive finding that does emerge from the Hoover School Experiment is the remarkable shift in attitude by the teachers. There is no question as to their preference for windowless classrooms, once they have had the experience of teaching in such an environment, and they are unanimous in their reasons for not wanting the windows: The children are no longer distracted by outside happenings when the classrooms become windowless, and besides the extra wall space can be put to good instructional use" (Larson et al., 1965, p. 55).

Attitudes Toward Windowless Classrooms

The investigations by Demos, Larson and their colleagues revealed that the absence of windows in the classroom did not have any noticeable effect upon such measures as academic performance, physical health and classroom behavior. Although their survey of attitudes toward the windowless classroom was limited, particularly in Larson's case, they found both favorable and unfavorable attitudes toward the absence of windows. The studies which will be reviewed next dealt specifically with student attitudes toward windowless classrooms. Because teacher attitudes were rarely investigated, it is not known if other teachers would express the positive attitudes found by Larson *et al*.

As might be expected, the findings from the various attitude studies are somewhat contradictory. Chambers (1963), for example, administered reaction sheets to determine attitudes toward windowless classrooms at the University of Tennessee and at elementary and secondary schools in New Mexico. In all three academic settings he found that teachers and students expressed a preference for the lack of outside distractions, the excellent temperature control, visual comfort, and ease of concentration. A small number of teachers and students complained about the lack of a view to the outside and expressed a desire to know more about the weather. Only one of the ninety-seven University students surveyed reported an unfavorable reaction to the absence of windows; all others expressed quite favorable opinions. Gingold (1971) found similar favorable reaction to controlled interior conditions.

Not all studies, however, have found favorable attitudes toward windowless classrooms. A study by Tikkanen (1970, 1972) used a questionnaire to compare the reactions of over 300 students to the physical environment of their classrooms in four schools with windows and four without.

When the questionnaires were evaluated, Tikkanen found that the overall ratings were similar. However, classrooms with windows were rated as having better lighting but also as being noisier with more outside distractions. In addition, some students in windowless classrooms also reported a greater ability to concentrate on their studies. When the preference for windows was measured, 48 percent of the students in the windowless school preferred that condition, while 43 percent would have preferred windows. Ninety-four percent of the students in the schools with windows preferred windows while only 4 percent would have preferred the windowless conditions. The preference for windows is evidently not altered by the extent of window area, because Tikkanen found that even in the schools with markedly reduced fenestration (1.4 percent to 6 percent of classroom areas), the students expressed the same strong preference for windows. Tikkanen did note, however, that the larger the window, the stronger the desire to see out.

In conclusion, Tikkanen (1970, p. 46) stated that "it is interesting to note that most of the student reasons for windows are psychological and, as such, may stand a lesser chance against the economic and security reasons that the school developers can offer. No evidence was uncovered

by this research that the windowless classroom would be in some way harmful to the majority of students, although there was some indication that small window areas were better than none. Small window areas would satisfy the desire to see outdoors to some extent, as having no windows would leave the desire totally unsatisfied."

Another study that revealed less favorable reaction to the windowless school was conducted by Karmel (1965). His research was designed to assess the psychological effect of the windowless classroom environment upon high school students' drawings. Ninth and tenth grade students (a total of 1217) at two schools in Illinois were asked to draw a picture of a school as completely as they could. One school had windows; the other did not. Three psychologists rated the pictures on presence or absence of windows, and on evidences of hostility or psychopathology. The judges did not know which school the students attended.

According to the psychologists' ratings, the children in the windowless school drew windows significantly more frequently than did the children in the windowed school. In addition, one judge put more of the drawings of the children from the windowless school into the hostile and severe psychopathological group. Karmel (1965, p. 278) stated: "These two observations suggest more unhappy or maladjusted children attending the windowless school, but whether the maladjustment was related to the lack of windows in the school building is beyond the scope of this paper. Judges did rate differently the drawings of students at the two schools which suggests a need for more research of peoples' perceptions of and reactions to living and working in windowless buildings."

A rather different approach was taken by Tognoli (1973), who examined the effects of environmental embellishments, such as windows, upon attitudes toward the experimental setting and upon short-term retention of verbal material. Although his study concerned variables other than windows, he found that subjects rated the presence of a window as substantially more pleasurable than its absence. The presence or absence of windows had no significant effect upon subjects' retention.

Most of the studies reviewed thus far have dealt with elementary or secondary students. Although many college buildings are built without windows, particularly science buildings where a need exists to control daylight, humidity, temperature, and dust, little is known about student reaction to these enclosures. As noted previously, Chambers (1963) determined that university students reacted quite favorably toward a seminar conducted in a windowless, controlled environment. Yet, when Sommer (1969) attempted to hold a class in a windowless room, the students petitioned violently to have the class moved to a room with windows. The conflict in findings from these two studies is characteristic of the varied reactions to windowless classrooms. Individual preferences appear to vary widely for reasons that are not always readily apparent. There is a great deal of mobility in the college setting unlike the elementary school, so that students rarely spend more than an hour or two in one classroom. Because they are not likely to be subjected to a windowless classroom for long periods of time, the impact of the absence of windows might be lessened for the college student.

Sommer (1969, p. 109-110) commented upon the windowless school argument by stating: "At present the pro-window forces still lack behavioral data in support of their case and argue on the basis of metaphor and supposition, but their arguments must be weighed against statistics such as those from the windowless school in New Mexico that is reported to have 40 percent greater efficiency in heating and cooling, constant light to prevent eye strain, partitions, doors, and walls, and 35 decibels or more noise reduction, and reduced maintenance costs." He claimed that the use of completely underground schools has provided evidence that full-blown claustrophobic reactions are extremely rare. He stated further that "Opponents [of the windowless school] now take recourse in the need for communion with nature, contact with the outside, and stimulus variation, which are more difficult to measure, and whose importance is not readily apparent. Should one show that communion with nature is reduced in windowless schools, is there 'evidence' that this is harmful to students?"

Similar favorable conclusions about windowless schools were expressed by Demos and Larson at the end of their studies. Concluding that windowless classrooms should have no adverse effects upon their users, Larson (1965, p. 56) stated: "The educational value of such a view should be assessed against the cost of installing and maintaining classroom windows. If the outside view is unpleasant or potentially disturbing there seems little point in having a window at all. On the initial basis of the Hoover School experiment, it is not likely that the children will be adversely affected by a total elimination of the schoolhouse fenestration."

If any single conclusion is to be reached from the windowless school studies, it is that the absence of windows does not appear to have much impact upon the students. Although some students do not perform as well in the windowless school, others do better. In general, the lack of windows does not improve performance, but neither does it appear to impair it. Some students like the situation; others, possibly a majority, would prefer to have windows. The most striking conclusion seems to be the absence of significant findings, either pro or con. Whether this is a fault of the experimental designs used, or a reflection of the real absence of any pronounced effect is not known. Yet, the absence of enthusiasm for the windowless design suggests that it should be used with some caution, particularly since the effects of long-term use of windowless classrooms have not been assessed.

Windowless Factories

Unlike the windowless classroom, there has been relatively little research into the attitude of employees toward windowless factories, even though these may well be the most frequently occurring form of windowless construction. Unlike schools, where the omission of windows appears to be almost a fad, in some factories the use of specialized manufacturing processes requires a clean, dust-free atmosphere with a controlled range of temperature and humidity (Manning, 1963; Hollister, 1968).

Perhaps because of the stringent requirements of the manufacturing process, there has been little research into employee reaction to windowless factories. Hollister (1968) suggested that there may be some belief that employee needs are secondary to those of the manufacturing process. Whatever the reason, most of the information on employee reaction is not based on formal investigations so that much of it is almost anecdotal.

A review of industrial lighting in windowless factories in Light and Lighting (1964) included comments by David Pritchard of the British Lighting Council about conditions within several windowless factories. He noted that interviews with personnel managers revealed very few employee complaints about the lack of windows. One personnel manager did indicate, however, that several employees had quit their jobs, complaining of claustrophobia and unhappiness with the windowless building. Nevertheless, most of the employees had seemed relatively content, even under what Pritchard thought were somewhat inadequate lighting levels. Pritchard claimed that the exclusion of daylight and the relatively low luminance levels did not appear to result in excessive employee complaints or mass resignations. He dismissed any hidden resentment with the following statement: "From this small sample, it does not seem so, although the fact that most, if not all, the work people were being paid on a piece rate might influence their attitude to their work and its environment. In offices, for example, where this incentive to work does not apply, there seems to be stronger opposition to the total exclusion of daylight. On the other hand, in basement floors of department stores, where people necessarily work in an

environment having no direct view of the world outside, there have (as far as is known) been no suggestions of adverse psychological effects or staff difficulties arising from this cause being experienced" (1964, p. 267).

There are some problems with Pritchard's conclusion that people are content with the working situation in windowless factories, because the only employee attitudes sampled were those volunteered as reasons for job resignation and as complaints to the personnel manager. As a result, it is not known what employee opinion would have been if it had been directly solicited.

Hollister (1968) also discussed several accounts of employee reaction to windowless factories. Most of the literature he reviewed is not at all recent, so that one does not know if employee reaction would still be as unfavorable as he suggested.

Hollister (1968) reported that when the first underground factories were built in Sweden in 1946, the employees expressed extremely negative attitudes, with many complaints of headaches and fatigue. As a result, a study was undertaken comparing various physical measures for two equivalent groups, one of which worked above ground, the other below. It was found that "whilst in 1949 it seems there were many more complaints of headaches, fatigue, eyeaches, nervousness and insomnia amongst those working underground, the incidence of absenteeism for this group was only slightly higher than for those working above ground and tended to decrease to the same level as employees became accustomed to the underground conditions". By 1958, "Blood tests on 100 people who had been working underground for 8 years showed no alteration in the normal

blood condition. But again, the psychological atmosphere remained sensitive" (Hollister, 1968, p. 64). Hollister commented further that "Trysin's work in Swedish underground factories gave similar conclusions. Initial complaints of fatigue, headaches, impaired vision and general depression were found to be due to inadequate lighting, ventilation and inappropriate color schemes. When these were remedied it appears that the complaints stopped. Trysin found it advisable to make rest periods sufficiently long to allow workers periods in naturally lit rooms or even outside" (Hollister, 1968, p. 64).

Hollister mentioned another investigator who examined employees of factories in Thuringia and found that there was a higher level of sick leave due to colds, stomach disorders and nervous disorders in windowless factories. Although this difference was attributed to the hiring of untrained, inexperienced females, the recommendation was made that windowless factories be used only when absolutely necessary. Still another unfavorable reaction to windowless factories in America is the following: "During the war employees broke so many wall panels that it became necessary to provide some visual contact with the outside world. Even when windows have been provided in the external wall there were numerous references to trouble with men breaking windows to get the 'feel' of fresh air in artificially ventilated plants, and it is recognized by designers that real evidence of air movement in hot weather is necessary to offset this. Sometimes the breaking of windows was associated with the use of blue obscured glass in the windows and visual relief was probably therefore a factor" (Hollister, 1968, p. 37).

Recently, Plant (1970) indicated some concern about the long-term photobiological effects of working under artificial illumination in windowless factories as well as about the loss of contact with the exterior world. He noted from some Russian and Czech literature that not only is absenteeism higher in windowless factories but that their occupants are more subject to headaches, faintness and sickness. A contrary opinion was given by Carlier (1969), who studied windowless factories in Belgium. He asserted that there ought not be any problem with windowless factories because the employees have no time to look out the windows. Furthermore, most of them are seated too far from the window to be able to distinguish anything, anyway. Carlier (1969) claimed that the way to avoid employee unhappiness is to convince them that the conditions in the windowless factory are far superior to those in a conventional factory.

Although Carlier's (1969) approach to human requirements for working conditions is unsympathetic, he makes an important point. Researchers doing surveys of attitudes toward buildings with and without windows may find it difficult to compare reactions to the two situations because the physical conditions of the windowless building may be far superior. For example, Manning (1967) noted that British factory owners have frequently assumed that their employees are likely to be unhappy with windowless factories and so have provided higher levels of amenity than are customary. In consequence, illumination levels are often higher; air conditioning is frequently used; lavish canteens, lavatories, and sports facilities are often provided; and the quality of color schemes and finishes is unusually good (Manning, 1967). Tikkanen suggested that "In

general, the interior design should be of a high standard as a partial compensation for the lack of windows", for windowless schools (1970, p. 16).

The conclusion one reaches after reviewing the sparse literature on windowless factories is that employees do not particularly like them. What is not known, however, is their long-term reaction to working in an evidently disliked environment. They may react to the situation with continuous, but mild resentment, or they may simply accept it without reservations. Further research is needed to determine if there are any long-term adverse effects of working in windowless factories.

Windowless Office Buildings

Although totally windowless office buildings are rare, unlike windowless factories, windowless offices within buildings with windows are common. These windowless spaces are a by-product of the "compact-block" design which results in buildings that are square and deep rather than thin and elongated. Such design means a reduction in land, construction and operating costs, as well as in energy loss through the (lessened) perimeter wall area (Hollister, 1968). In the United States, these buildings customarily have artificial lighting, mechanical ventilation and heating/cooling systems. When windows are provided, they are frequently sealed to reduce needless demands on the heating and cooling system.

Ruys assessed the subject's reaction to the physical environment of her office with a questionnaire. The final question asked her to rate the intensity of her feelings toward the absence of windows and state why she felt this way.

For the most part, the subjects indicated that they were happy with their offices. Almost 45 percent thought that their offices were large enough, and almost 90 percent believed the lighting levels to be adequate. Nevertheless, despite overall satisfaction, about 90 percent expressed dissatisfaction with the lack of windows, and almost 50 percent thought that the lack of windows affected them or their work adversely. When asked what they disliked most about their office, 35 percent responded spontaneously, "the lack of windows". The subjects gave the following reasons for disliking their windowless offices: 1) no daylight; 2) poor ventilation; 3) inability to know about the weather; 4) inability to see out and have a view; 5) feelings of being cooped-up, isolation and claustrophobia; and 6) feelings of depression and tension.

Ruys then examined the effect of office size, color, illumination levels, and nearness to an exterior window upon dislike for the windowless office. He discovered, however, the presence of such factors as access to a nearby window, bright lights, or warm colors, did not alter the subject's dislike of the windowless office. Consequently, Ruys decided that the desire for windows is so strong for subjects in small, windowless offices that he could not make any architectural recommendations to increase satisfaction with them.

The result of the compact design is that many people normally work in both large and small windowless offices. Although relatively few studies have actually assessed individual reaction to working in a windowless office, there does appear to be a widespread opinion that people do not like to work in windowless offices. This appears to be based on personal reactions and feelings, rather than any actual experimental research (Hopkinson and Collins, 1970; Hollister, 1968).

An experimental investigation of psychological reaction to windowless offices was conducted by Ruys (1970). He wanted to determine an employee's satisfaction or dissatisfaction with the absence of windows. He also wanted to find out what improvements might be made to modify or alter the reaction to the windowless condition. As an architect, he was concerned about architectural changes that might improve personal satisfaction with windowless offices.

The subjects of Ruys' study were 139 female office workers in 5 buildings containing windowless offices in the Seattle, Washington area. Almost 60 percent of the subjects were the sole occupant of an office; only 5 percent occupied an office with more than three people. Most of the offices were relatively small, ranging from 3.2 sq. m. to 14.8 sq. m. (35 sq. ft. to 165 sq. ft). Female subjects were deliberately selected because Ruys felt that, as a general rule, more females occupy windowless offices.

Ruys' investigations were limited to subjects who did paper work in small, often single-occupant offices. As a result, their opportunities for movement out of their officesor for casual interaction with other employees were quite restricted. These restrictions may have

increased their dislike of the windowless situation. The dislike might be lessened in a large, open office with frequent opportunities for movement and interaction with people.

Another brief survey of office personnel was done by Sommer (1974). He "interviewed employees in several underground offices. For them being underground as well as windowless was also a consideration. I was struck by the frequency with which employees hung landscape pictures and posters on the walls. Wild animals, seascapes, forest scenes, and travel posters became surrogate windows. The major complaints concerned the stuffiness and stale air, the lack of change and stimulation, and the unnaturalness of being underground all day" (Sommer, 1974, p. 115). Sommer also noted a tendency for firms to place lower echelon personnel in windowless spaces while the executives had top floor offices with windows. He commented further that the windowless (underground) situation "is harder to endure because of the workers' knowledge that the executives have large offices upstairs with splendid views of the city" (Sommer, 1974, p. 119).

Sommer's and Ruys' investigations suggest that the reaction of office personnel toward windowless offices is quite unfavorable. These findings differ from those found for windowless factories. The difference may be due to the sheer size of the working area; rarely are factory workers confined to small rooms with only one or two other people, as were Ruys' subjects. Manning (1968) suggested, however, that there are inherent differences between employees in factories and in offices. He stated that "the attitude of office staff to their

working environment is very different from that of factory workers to theirs. On the whole, people who work in factories seem prepared to accept their environment largely as they find it, and allow considerable latitude in standards of light, thermal conditions, noise, and other matters. By contrast, office staff seem much less ready to accept what they are given and much more prone to criticize" (Manning, 1967, p. 162). Unfortunately, the same type of research has not been done for both situations. Were a more exhaustive investigation to be made of factory workers, the findings might be more comparable to those from office workers.

Hospitals

The hospital ward is similar to a small office in that it is a restricted, cramped situation from which a window offers some momentary escape. Perhaps for this reason, hospital wards are very rarely built without windows (Hollister, 1968). Nevertheless, the increasing use of the "block" design has also affected hospitals, so that a large (urban) hospital often consists of perimeter rooms with windows built around an internal, windowless core. These internal rooms are generally used as nurses' stations, operating rooms, and laboratories. Nevertheless, it has occasionally been convenient to locate an intensive care unit in such areas because it requires specialized equipment and personnel for continuous monitoring of seriously ill patients.

Kornfeld (1969) commented that, although locating the unit in a central, windowless space might be more efficient, patient reaction to the lack of windows could be rather unfavorable. A study by Wilson (1969) investigated patient reaction to windowless intensive care units. Before discussing Wilson's experiment though, it is important to understand something of the overall psychological reaction to intensive care units, whether with or without windows.

An intensive care unit is a small (usually fewer than 30 beds), open ward in which continuous nursing care and monitoring of bodily function occurs. Because of the open, relatively impersonal situation and the common occurrence of morbid sights and sounds, coupled with the presence of serious illness or surgery, the intensive care unit itself can be extremely stressful (Margolis, 1967). Furthermore, the patients are confined to their beds so that their sphere of activity is severely limited. Whether due to the stress of surgery or of the unit itself, some patients develop a syndrome known as "post-operative delirium" (Abram and Gill, 1961). This syndrome can be defined "as an acute brain syndrome characterized by impairment of orientation, memory, intellectual function and judgment with lability of affect" (Morse and Litin, 1969, p. 389). The delirium is not the product of organic brain disease; rather it is a multi-determined syndrome to which age, sex, alcoholism, drug abuse, and excessive pre-operative anxiety as well as sleep deprivation and perceptual distortion in the recovery room (due to anesthesia or accidental loss of glasses and hearing aids) all contribute (Morse and Litin, 1969); Kornfeld, 1969). Thus, post-operative

delirium can develop in almost any patient placed in an intensive care unit following serious illness or surgery.

Wilson (1972) conducted a study to determine whether the absence of windows in such a unit would increase patient stress as reflected by an increased incidence of post-operative delirium. He examined patients in two general hospitals in the El Dorado, Arkansas area each of which had an intensive care unit. One unit had windows, one did not. Wilson (1972, p. 225) stated: "Both intensive care units are within general hospitals accepting random admission from the same community, treated by the same physicians who make up the medical staffs of both hospitals. Except for obstetrics both hospitals offer similar services. They also have similar bed capacities as well as comparable nursing staffs." Although the intensive care unit is itself a stressful situation, Wilson (1972) hypothesized that the absence of windows might increase this stress.

Wilson studied 50 patients in each unit who had received major surgical care requiring general anesthesia. These patients were similar in terms of age and general physical condition both before and after surgery. There were no readily apparent differences in treatment, medication or patient-to-nurse ratio between hospitals, so that none of the patients should have been particularly predisposed to post-operative delirium.

Although both groups of patients were essentially similar, Wilson found that more than twice as many patients in the windowless intensive care unit developed post-operative delirium (40% vs 18%). There was also a greater incidence of post-surgical depression among those patients in the windowless unit who did not develop post-operative delirium.

Because of the similarities between both groups of patients, Wilson attributed the increased incidence of delirium in the windowless unit to the absence of windows. He theorized that windows apparently provide some sort of necessary psychological escape from the grim realities of surgery. This additional stress is sufficient to tip the balance toward a brief psychotic episode for a large percentage of patients.

Wilson's findings suggest that windows should be provided in all hospital wards. In an article commenting upon Wilson's research, Vaisrub (1972) stressed that windows ought to be provided for hospital patients regardless of cost. In conclusion, although Wilson's findings should not be taken as concluding that all patients deprived of windows will develop delirium, they do indicate that the absence of windows can contribute severe additional stress. Whether this situation is also stressful for hospital personnel was not studied.

Other Windowless Environments

Although some favorable attitudes were expressed about windowless schools, most of the reactions to other windowless environments, such as the office or hospital, were rather unfavorable. Yet, there are some situations in which the absence of windows is so common as to be unremarkable. For example, theatres, cinemas, restaurants, bowling alleys, night clubs, department stores, museums and art galleries are frequently designed as windowless buildings. In some cases, such as a theater or an art gallery, the absence of windows removes a source of unnecessary distraction, and allows greater concentration. Of course,

there is also greater physical security and better control of the lighting in a windowless museum or theater. People in such buildings appear to have few complaints about the absence of windows.

"The department store seems to be one type of building which has operated successfully for many years within a windowless or quasi-windowless environment" (Hollister, 1968, p. 47). Hollister suggested that one of the reasons for the acceptance of windowless department stores is that each department store floor is a self-contained space directed toward a single end -- the promotion of sales. Outside distractions are unnecessary and undesirable. "The reasons for this [acceptance] seem to result from the large size of the interior space, the constant activity of a busy store, and the wide range of auditory, visual and tactile experiences to which the occupants are exposed. The main quality of the interior environment is that it is dynamic" (Hollister, 1968, p. 47). Hollister noted that although large department stores are frequently windowless, small shops rarely are. He suggested that tolerance of windowless interiors may be greater for large spaces than for small.

While the greater dynamic quality of the department store may be responsible for acceptance of the lack of windows, an investigation into other apparently accepted windowless interiors might be quite fruitful and lead to a greater understanding of the adverse reaction to some windowless situations.

Safety

In addition to the dislike that many people express for windowless environments, there are some other drawbacks to windowless buildings which deserve consideration. The most obvious of these is fire safety. Griffith (1962) and Hollister (1968) both noted that windows can provide an excellent means of escaping from a building fire, even though they may not be the preferred exit. Juillerat (1964) reviewed a number of serious fires in windowless buildings and concluded that their severity was accentuated by the inability to open windows to vent both smoke and fire. He claimed also that a greater number of lives were lost because people were unable to leave the building, while firemen were unable to enter it to rescue them. The implication of these articles is that fear of being trapped in a burning windowless building is not completely unrealistic.

Additional drawbacks to windowless buildings from a safety standpoint result from their total reliance on artificial illumination and ventilation systems. Any emergency involving a loss of power is a potentially dangerous situation in a windowless building, unless auxiliary power is immediately available.

Although there are some potential dangers associated with windowless buildings, buildings with windows are not completely free from possible hazard. In the case of fire, the windows may shatter too easily, allowing the fire to spread rapidly (Markus, 1962). On the other hand, the glass may not break easily enough, making it difficult to vent the fire or escape the building. In ordinary situations, there is the possibility

of accidental breakage with attendant injury. Although these latter situations can be avoided or minimized by the use of safety glass, such glass is not presently required for windows in buildings by any state code.

Summary

Although the preceding review of the literature has discussed the reaction to different windowless building types, it has not considered any general factors which might influence this reaction. It is obvious that variables such as the amount of time spent in a windowless space or the type of task performed might influence a person's attitude toward it. The differences in attitude found in the windowless school research suggest that individual differences might also influence a person's reaction to a windowless space.

About the only field of research which has examined individual reaction to the absence of sensory stimuli is that into "sensory deprivation", in which all stimulation is removed for long periods of time. Although a windowless space does not deprive a person of all sensory stimuli, it does reduce the amount of visual, auditory and thermal input he can receive from the outside world. Wilson (1972) observed that many of the symptoms of patients in windowless intensive care units were similar to those of persons undergoing sensory deprivation. Also noting similarities in these two situations, Hollister commented that because there are "extremely wide differences in reactions to sensory deprivation", it is likely "that the same will be found in research on the effects of windowless buildings; i.e. for some people or some measures, the absence of windows will be beneficial; for

other people or other measures, the absence of windows will be detrimental" (Hollister, 1968, p. 67). As in sensory deprivation research the length of time spent in a windowless environment may also be important. In this context, another of Hollister's remarks appears to be relevant: "The difficulty about most of the work on sensory restriction is that it tends to be based on work done in situations where there was a large amount of deprivation for relatively short periods. Moreover, these were often artificial experimental situations with volunteer subjects. In the windowless building situation, the anxiety that one obviously has in mind is the effect of relatively mild deprivation over extended periods" (Hollister, 1968, p. 67).

These statements suggest that both personality variables and the length of time spent in a windowless environment can determine personal reaction to it. It also appears evident that a boring or monotonous job might increase dislike of a windowless situation. Hopkinson and Collins (1970, p. 266) observed that the degree of dislike is minimized in underground railway stations and department stores and "greater in places where there seems no good reason for cutting out the daylight except profit to the management, or where a boring job has to be done which permits the attention to wander."

In addition, evaluation of the various studies suggests that the environment of the enclosure involved may also be critical in determining the reaction to a windowless space. When the various studies are considered together, the reaction to the absence of windows appears to form a continuum with the most adverse reaction to the intensive care unit at one end and the least to such public facilities as department

stores and theaters at the other. Reaction to offices, factories and schools appears to fall in the middle (in about that order). Thus, at one extreme of the continuum, the absence of windows can further the development of a brief psychotic episode. Yet, at the other, their absence may not even be noticed. These observations imply that some windowless situations are, in general, much less tolerable than others.

Further thought about the various studies indicates that windowless spaces vary widely in number of occupants, size, amount of activity, and opportunity for personal interaction. The small, restricted environments with little activity or personal interaction appear to be the ones in which the absence of windows is most noticeable. The intensive care unit, for example, is a relatively small area in which the patient's movement is limited to his bed and his activities are reduced to the maintenance of bodily function. Similarly in a small office occupied by only one or two people, personal movement can be quite limited, conversation may be discouraged, and the task can be repetitive and boring. In these situations, adverse reactions toward the absence of windows arise. On the other hand, there is the school, or the department store, each characterized by variety, activity and personal interaction. In these latter <u>dynamic</u> situations, unlike the previously mentioned <u>static</u> ones, the absence of windows is not especially noteworthy. Hence, it appears as though the smaller and more restricted a windowless space is, the more repetitive and monotonous a task is, and the more reduced the freedom of movement and interaction its inhabitants have, the more unpleasant and oppressive it will be. Such static and confined situations appear to generate a certain amount of tension which is accentuated by

the absence of a window. Yet, in these same situations the mere presence of a window is apparently sufficient to alleviate some unpleasantness. Evidently, the window offers the possibility of a brief respite or momentary escape from somewhat undesirable surroundings. Furthermore, a window affords the continuous possibility of escape for each individual to use as he chooses.

Although reactions to windowless environments can vary from fervent dislike to calm acceptance, the preceding literature review indicates that people are not particularly enthusiastic about windowless spaces. Tolerance or dislike appears to be the rule, rather than the exception. While windows are sorely missed in static, restricted spaces, more active, dynamic situations are quite tolerable without windows. It is clear that the needs of the users, as well as the task, ought to be seriously evaluated before a building is designed as windowless. Despite their convenience, windowless buildings should not be considered as the only design solution for energy conservation.

Energy waste can be reduced through sensible design. Windows can be double- or triple-glazed; special solar glasses are available; shading devices, both internal and external can be used; natural vegetation can be employed; and buildings can be oriented properly with respect to the sun and prevailing winds. With these various energy-saving possibilities in mind, let us turn to a consideration of the functions and benefits obtained from windows in buildings.

SECTION II

BENEFITS AND PSYCHOLOGICAL FUNCTIONS OF WINDOWS

The knowledge that reaction to many windowless spaces is less than enthusiastic should spur research into developing other methods for minimizing energy loss through windows. One of the most obvious alternatives is to reduce window area. Before this approach is adopted, it is necessary to consider the benefits provided by windows. Once the benefits are known, it then becomes possible to determine the most acceptable parameters of size, shape, and position that would fulfill human requirements, and reduce energy consumption.

In Section I, the general desirability of windows was inferred from the somewhat negative reaction to windowless spaces. In Section II, the reasons underlying the frequently expressed desire for windows will be considered. Why do people want windows? What benefits do they provide? How small, or large, does a window have to be to provide the desired benefits?

A number of different approaches have been taken to answer questions such as these. The trend in research, unlike that reviewed in Section I, has been for each experimenter to isolate a specific aspect of a window deemed important for study -- that is, a parametric approach. As a result, there are many investigations into a single topic, such as sunshine, view or spaciousness, but relatively few comprehensive evaluations of the benefits of windows. Although each of these specific topics probably contribute to a person's satisfaction with a window, their total impact has rarely been evaluated in the same manner as the impact of a windowless environment.

View

When the benefits of windows are considered, perhaps the one that repeatedly emerges is that of "view". Even in the studies of windowless environments, subjects regularly stated a desire for contact with the external world or a view. Although the word "view" tends to imply some sort of beautiful, pastoral scene, it is considered here to refer simply to the scene beyond the window. As such, it can be good or bad, beautiful or ugly, dynamic or static, but always different from the scene within the interior space.

Commenting upon the importance of a view to people in buildings, Manning (1967 p. 23) stated: "the uniquely important characteristics of windows appear to be their provision of a view: people within buildings seem to need some contact with the outside world." This opinion was supported in a study by Wells (1965) who surveyed office workers to determine if they could accurately estimate the proportion of daylight in a primarily artificially lit office. He determined that 89 percent of those surveyed felt that it was desirable to be able to look outside even if there was plenty of artificial lighting available. Only 1 percent stated that they did not think it important. In addition, 69 percent believed that daylight provided a better quality of illumination for office work than artificial light. Only 3 percent believed that artificial light was superior. Wells (1965) concluded that, although people far from a window consistently over-estimate the percentage of daylight that they work by, this does not alter their belief that a view is necessary and that daylight is the best illuminant.

Jackson and Holmes (1973a, 1973b) expanded upon the importance of a view for an office worker. "He looks out also for release, in the form of movement compared with his static situation inside. He looks out of the window to check the weather and to reassure himself that life is still going on in the 'real' world outside. The window many serve as a very real release from claustrophobia arising from a small office." Yet, "in spite of all this, there is little hard knowledge about the purpose that is served by the view outside. There is some indication that the information content can be quite small; even a brick wall six feet away outside a window is much preferrable to a brick wall at the same distance inside the same room. An open door or a glass partition between two offices may serve a similar purpose but somehow it isn't quite as good" (Jackson and Holmes, 1973b, p. 80).

Although the desire for a view out appears well-established, the characteristics which make it more or less desirable are not as well understood. Among the studies which have dealt with this question is one by Markus (1967a, 1967b), who assessed view preference in a normal working environment. He surveyed 400 office workers who occupied 9 floors of a 12 story building in Bristol, England. Almost all the rooms were large open-plan offices so that all subjects had some access to a window. During the survey, Markus determined a subject's attitudes toward such aspects of his office environment as noise, illumination levels, size, toilet and canteen facilities, sunshine and view. He also assessed the relative importance of the view and the windows in reference to other environmental aspects of the office.

About 70 percent of the subjects rated the view as good, and about 25 percent rated it as adequate. Markus commented that "This result is not surprising in view of the nature of the site and siting of the Robinson building, with open city and distant rural views on all sides; nor is anybody situated so far from a window that he suffers a serious loss of view" (p. 67). There were, however, differences in the quality of the view, in that one orientation (Northwest) faced old city spires, trees and distant hills; another (Northeast) faced old bombed sites and parking lots; and the other two (Southeast and Southwest) faced much less distinctive views. Not too surprisingly, the subjects were more content with the "outstanding" view to the Northwest, and least with that to the Southeast. Markus' results revealed that a majority of subjects (88 percent) preferred views of the distant city and landscape. Only 8 percent preferred a view of ground and nearby buildings; and only 4 percent preferred a view of the sky. Subjects who were on the lower floors of the building tended to prefer views of the ground and nearby buildings to a greater extent than those on upper floors.

Markus found the subject's distance from the window affected his satisfaction with the view. The greater the distance, the less satisfied the subject was and the more he desired to sit nearer a window. Although almost all the female subjects expressed more dissatisfaction with the view than their male counterparts, this difference appeared to be the result of the seating arrangement rather than a sex difference. It appeared that the majority of females were seated at a greater distance from the window. When subjects were

questioned about sunshine, an overwhelming majority (86 percent) stated a desire for it all year round. Although more females desired sunshine, this preference appears to be related to their greater distance from the window.

Finally, when subjects were asked to rank order view and sunshine in a list of ten environmental factors, Markus found that most ranked them among the last four items. He attributed this low ranking to the fact that the subjects' needsfor view and sunshine were adequately met, so that they tended to overlook these two factors.

In conclusion, Markus discussed the need to determine the best window design for fulfilling human needs. He noted that "it is surprising to find virtually no work to establish the minimum and optimum performance of windows with regard to their fundamental function -- acting as visual apertures enabling building occupiers to remain linked to the external world in some way. The design of windows as view-giving elements has remained largely a matter of chance being subject to stylistic vagaries and fashion" (Markus, 1967b, p. 76). Markus proposed that the information content of the view is critical in determining a person's satisfaction with his windows. In order to maximize this content, he recommended vertical windows providing information about three layers: the sky (upward), the city-scape (horizontal), and the ground (downward). In addition, Markus suggested that a "good" view should provide a certain amount of dynamic change.

Markus cautioned that the benefit of his recommendations may be lost upon people who are seated at a distance from a window. As a person's distance from the window increases, the window aperture appears smaller; the extreme portions of the view disappear, and "there is a change from the sensation of being 'in', a 'part' of the exterior world to that of observing 'from outside' (really inside); now the view appears more or less as a picture being on the wall, framed by the window frame, and not as three-dimensional reality" (Markus, 1967a, p. 104). Similarly, much of the near foreground, which contains most of the detailed and informative portion of the view, is no longer distinct from the upper floors of a building. Because Markus dealt with the overall reaction to an office environment, he was not able to explore in detail the characteristics of a view that make it more or less acceptable. Although his subjects found some scenes, such as parking lots, less desirable than others, they did not provide much insight into the reasons underlying these preferences.

The importance of view to office workers was also substantiated in another study, this one conducted by Cooper, Wiltshire and Hardy (1973). Using an approach somewhat similar to that of Markus, Cooper et al. administered a comprehensive questionnaire to the occupants of eleven office buildings. Although the authors were primarily concerned with the reaction to special types of window glass, they also assessed opinions about the entire office environment, including the view.

The results of the questionnaire were somewhat different than expected. First of all, only 3 percent of the subjects rated the presence of a "good view out" as the most important feature in making the office a desirable place to work. Nevertheless, only 13 percent of the subjects said that a good view was unimportant. They rated the lighting and overall thermal conditions as the most important contributors to the pleasantness of the office environment. (At least 25 percent of the subjects complained about the heating and ventilation in their buildings.)

Although the presence of a view was not rated as the most important aspect of an office, the subjects had definite opinions about the kind of view they found desirable. The survey results showed that the greater the variety of distant objects that could be seen, the more adequate and pleasant the view was judged. View content, height above the ground and age of the respondent also affected the judgments of the adequacy and pleasantness of the view. Although size of the window did not have much effect upon these judgments, the authors speculated that larger windows would increase view content, and increase the pleasantness of the view.

Cooper et al. commented that the relative lack of importance of view suggests that "most people will be satisfied, provided they can see out, even if the view is restricted. In making decisions about facade design it would therefore appear to be unreasonable to give priority to the provision of an extensive view if this has a detrimental effect on the internal environment" (Cooper et al., 1973 p. 12). Nevertheless, the authors suggested that while a good view may not be of paramount importance for most people, a complete absence of a view would be greatly

disliked. In other words, although it might be simplest in engineering terms to ensure good lighting, heating and ventilation by building without any windows, such a solution would be very unpopular.

The studies by Cooper et al. and by Markus were limited to an assessment of the reaction to only a few different views. In the next two studies, a wide variety of views were simulated in an attempt to define the characteristics of a "good" view.

The first simulation study was conducted by Ludlow (1972) who had 15 subjects rate a series of 36 slides projected onto a sort of "window". These slides simulated a fairly typical view seen by an office person seated 2.7 meters (8.9 ft.) from a window. Ludlow had his subjects rate the slides on a bipolar, good-bad scale, and comment about them while he recorded their viewing time. Ludlow obtained three measures of satisfaction: evaluative rating, general comments, and length of viewing time. The general comments were used to develop a list of key adjectives describing the scenes.

The results indicated that the better a slide is rated on a "good-bad" scale, the longer it is viewed. Ludlow commented that: "This is interesting in that it might be assumed that people would inspect slides for a longer time when it is difficult to make a decision or else where they have more remarks to make. As this is not necessarily the case, it must be assumed that viewing time directly reflects satisfaction" (1972, p. 4).

The list of key adjectives was evaluated to determine some of the criteria upon which the subjects based their satisfaction. From this evaluation, Ludlow predicted some trends in the preferred content of a view. One such trend was a preference for a more complex structural organization with a wide range of possible variations. Another prediction was a desire for far and mid-distant views containing a balance of man-made and natural elements. Variations in shape, color, brightness, texture and sky quality were preferred, suggesting that the possibility of change in a scene was important. Ludlow also noted an apparent preference for detachment, rather than direct involvement in the scene. "Sensory connotations of smell, noise, dust, etc., are important in that they have the effect of depressing the real value of the visual scene" (Ludlow, 1972, p. 8).

Although Ludlow's results suggested a desire for complex scenes with the potential for change and surprise, there may be an optimum level for such things as movement, human activity, brightness and color. However, such dynamic characteristics are difficult to evaluate with static slides. Ludlow (1974) currently is attempting to discover if subject preferences are similar for actual views from office buildings. His preliminary results indicate that people do evaluate real views along dimensions similar to those used to evaluate slides of views.

In another approach, Kaplan and Wendt (1972) evaluated the effect of complexity upon preferences for outside scenes. Although the authors were not specifically concerned with view through a window, their findings appear relevant to the topic. When they asked subjects to rate 56 color slides for both complexity and preference, nature scenes were

preferred to urban scenes. Subjects appeared to prefer scenes that were judged complex, but complex nature scenes were preferred to complex urban scenes. Kaplan and Wendt (1972, p. 628-1) commented that "man has a preference for the visual patterns characteristic of natural environments, and further, that this preference is not reducible to the complexity" of the scene.

In conclusion, the four studies that have evaluated the characteristics of a desirable view indicate that one of its most important features is complexity or information content. Another property of a "good" view is the provision of some information about the sky, the horizon, and the ground. Still another appears to be the satisfaction of a desire to see nature rather than urban scenes. Although none of these studies actually evaluated the appeal of a moving, changing scene, almost all the researchers believed that movement is also an essential quality of a "good" view.

Window Dimensions

The acceptability of a view is intimately related to the size and shape of the window through which it is seen. Intuitively, it appears as though a large window occupying most of the window wall could provide the best view. Yet, in general, large windows result in more energy loss than smaller windows, so that they are less desirable from an energy conservation viewpoint. Hence, the question arises as to what size and shape would satisfy the desire for a view, and yet still be small enough to reduce excessive energy consumption.

When window area is reduced from the full expanse of the exterior wall to some smaller size, then the shape and positioning become critical. As noted in the previous section, Markus (1967a, 1974) suggested that windows be designed to optimize the view out. Keeping this criterion in mind, let us review some of the studies that have examined "optimum" and "minimal acceptable" window sizes and shapes.

A number of investigators have attempted to define a range of acceptable window sizes and shapes through the use of scale model simulation techniques. With a scale model, a typical office environment can be represented complete with miniature furniture to give an illusion of reality. A subject can easily arrange the shape, size and location of an office window in a model to suit his preference. Variables such as view, building orientation and type of glazing can also be readily manipulated.

In an investigation of minimum acceptable window size, Ne'eman and Hopkinson (1970) used two models, one full-scale and one one-tenth scale, in three different locations with 319 subjects. Minimum acceptable window size was determined as a function of the dimensions of the room, the number of apertures, the outside view, the weather, external illumination levels, and two window heights 5-ft and 7-ft (1.5m and 2.1m). In all these conditions, a fixed 3-ft high (.9m) sill was used, along with two viewing angles.

Most of the parameters evaluated did affect the subjects' judgments of window size. Use of the one-tenth scale model revealed that subjects could define a "minimum acceptable window size" in all cases except when the view outside was uniformly bright and featureless. The use of the

full-scale model revealed that view, distance from the window, window height and visual angle all affected the subjects' judgments of acceptable size. One of the most important parameters proved to be the type of view. Ne'eman and Hopkinson found that subjects preferred wider windows (10.10 ft, 3.1m) for views of near objects than they did for distant objects (7.9 ft, 2.4m). The researchers related these differences to the subjects' need for intelligible information about the outside world. "Near objects attract more attention and require a wider opening to be wholly seen. On the other hand, distant objects cannot be observed in detail and because of the distance, their apparent size is smaller. A smaller window can, in this case, satisfy our curiosity. It is believed that this attention to the outer world is essential to relieve the sense of enclosure, and to provide muscular relief to the eye by allowing it to focus at a distance" (Ne'eman and Hopkinson, 1970, p. 27).

Ne'eman and Hopkinson found conflicting desires for window height. In one location, subjects preferred taller windows (7 ft, 2.1m) above a fixed 3 ft (0.9m) sill, than they did in the second location (5 ft, 1.5m). The authors inferred from this discrepancy that height is less critical than width in determining window size preferences. Apparently, increased height does not provide as much visual information as does increased width.

Ne'eman and Hopkinson also determined that acceptable window width was directly proportional to a subject's distance from the window, and determined a constant ratio of window width to subject distance.

Thus, even from different viewing positions and angles, the judgment of minimum acceptable window width depended primarily on the subject's distance from the window.

Ne'eman and Hopkinson observed that for a rear viewing position in a room with a window wall 24 ft long and 10 ft high (7.3m by 3.05m), the subjects' mean setting of window width was 8 ft (2.4m). Window height was fixed at 7 ft (2.1m). These dimensions indicate that the window occupied about 25 percent of the window wall. In order to obtain a window size that would satisfy at least 85 percent of the subjects, the mean window width had to be increased to 11 ft (3.4m). In the latter case, the window occupied about 35 percent of the window wall. Although Ne'eman and Hopkinson did not discuss their findings in terms of percentage of the window wall, it seems reasonable to convert their results to this measure since other researchers have used it extensively.

In addition, Ne'eman and Hopkinson found that increasing the window wall width from 24 ft (7.3m) to 72 ft (21.9m), and the number of windows from one to three through the use of mirrors, altered the subjects' judgments of acceptable window width. Briefly, the authors discovered that the angle subtended by the window wall was critical so that "for angular width below 60° it can be assumed that the width is additive, i.e. the minimum acceptable width can be divided into several parts, which together yield the same overall width, and yet provide subjective satisfaction" (Ne'eman and Hopkinson, 1970, p. 25). The implication of these findings is that if total amount of window area

is to be limited, and several windows are to be used, these ought to be placed so that they fall within a viewing angle of 60° or less. Any window located outside this region will be ignored.

The scale model approach was also taken by Keighley (1973a, 1973b), who investigated the effects of reduced window area in offices. In his first study, Keighley investigated the preferred location and shape of a window occupying only 20 percent of the window wall area. He used a one-twelfth scale model to simulate a large, open office in size, lighting and furnishings in both experiments. In the window wall of this model there was an aperture whose dimensions could be varied. Through this "window" 8 different color transparencies were projected to simulate different views as seen from different floors of a building.

Keighley had 30 subjects view the model as if it were their office. They were then asked to adjust the shape and location of the window to the most desirable dimensions for the 8 different views. During the experiment each subject's eye level was about 1.1 meter (3.36 ft) above the floor, as though he were seated in an office.

Keighley concluded that his subjects were most influenced by the external view in their choice of the preferred shape and location of the window. They wanted to see the ground, nearby buildings and the sky in a single view. They preferred a wide lateral scan so they selected aperture settings which produced wide rather than tall windows. Contrary to Markus' predictions, in no case did they select a tall window, even when this would have given them a better view of the sky. They tended to place the window sill somewhat below eye level, and to position the window horizontally in the center of the window wall.

In Keighley's study, view appeared to be the most important characteristic determining window shape preference. He commented: "There can be little doubt that a view to the exterior is an important aspect of the visual requirements of a building's occupants. View requirements appear to be best satisfied by horizontal apertures the dimensions of which are determined primarily by the elevation of the skyline. Ranges of sill heights from 0.7 to 1.1m (2.31 to 3.63 ft) and window head heights from 1.8 to 2.4m (5.94 to 7.92 ft) are indicated as optimum values according to the kind of outside view. Requirements are probably less decisive for fully obstructed views because of the loss of important cues, but nevertheless indicate a basically horizontal shape" (Keighley, 1973, p. 319).

In Keighley's second study (1973b), he investigated the preferred arrangement for several "windows" whose total area occupied only 20 percent of the window wall. He also evaluated subject preference for window size and position when no restrictions were placed upon window area. In each situation three different views could be seen through the apertures of the same scale model used in the first experiment. One view represented a distant city skyline; one depicted a more restricted city scene; and one was limited to the facade of a nearby building. Unlike the previous study, subjects did not adjust the apertures themselves. Rather, they rated each window-view combination on a five-point scale of satisfaction.

Keighley found that, when total window area was restricted and the number of apertures varied, subjects were dissatisfied with a large number of apertures and with very narrow apertures. As in the previous study, satisfaction with window height was dependent upon the view. Thus, window height was set lowest for a distant city scene, intermediate for a nearby facade, and highest for a restricted city scene with an elevated skyline. When total window area was limited to 20 percent, however, a horizontal aperture was preferred to a vertical. The use of several apertures of different shapes was found to be particularly unsatisfactory, because supplementary, narrow, vertical strips were completely ignored. As a result, Keighley concluded that the use of different sorts of apertures in combination was impractical.

Keighley found that his subjects were also dissatisfied with increasing mullion width possibly because it breaks up the view. Dissatisfaction with increased mullion width was greatest for a distant view, and least for a nearby view.

When Keighley measured subject satisfaction with different window areas, he found that windows occupying 10 percent or less of the window wall were regarded as extremely unsatisfactory. Satisfaction was greater for a window occupying 20 percent or more of the wall while windows 20 percent or larger were evaluated most satisfactory. These findings led Keighley to conclude that "Evidently window area is of considerable importance for view satisfaction, particularly over the range which constitutes reduced fenestration" (Keighley, 1973a, p. 327).

Although Keighley's findings from both studies indicated many of the variables that affect satisfaction with office windows, he himself noted that judgment must be exercised in applying his findings to actual situations. First of all, he noted that a scale model represents only one specific situation. It is entirely possible that satisfaction might vary with the viewer's distance from the window, office layout, and variation in view. Furthermore, to quote Keighley again, "The dynamic aspects of the view-window relationship could not be simulated during the experiments, for example, by movement of the observer about the room or by providing changes such as would normally occur in the outside scene" (p. 330).

Although the applicability of Keighley's findings to all design situations is doubtful, his work is unique in providing some idea of the range of acceptable window sizes. Furthermore, he has isolated some of the variables such as shape, mullion width, and view, which can affect satisfaction. The results found by Keighley, and Ne'eman and Hopkinson are a strong indication that there are window sizes which are too small to be acceptable. If a recommendation were to be made from this research, it would be that windows should occupy at least 20 to 30 percent of the window wall. In addition, Keighley's research work reinforces that of others who indicate that view is of paramount importance in determining a person's satisfaction with a window.

Illumination

As noted previously, windows can be used as light sources during the day. The quality of the illumination provided by both daylight and sunshine seems to have a tremendous psychological impact upon people in buildings. Although both sunshine and daylight provide illumination, they have frequently been treated separately. Thus, the literature on sunshine deals with its "psychological" benefits. That on daylight is concerned more with the amount and quality of illumination provided. Furthermore, the bulk of the work on sunshine has been done in the residential environment. Daylighting studies, on the other hand, have concentrated on school and office environments. As a result, the effects of sunshine and daylight will be considered separately.

Daylight

Daylight, while a good source of illumination, is rarely used as the only illuminant in most buildings. In many cases, it is used to supplement artificial lighting, and to enhance the overall quality of the room illumination. Concern about the quality of daylight has led to investigations primarily by light engineers into the benefits and functions of daylight. While many of these investigations have sampled only a few people (usually other lighting experts), their opinions do provide some insight into the properties of daylight that make it desirable.

Ne'eman and Hopkinson (1973, p. 1) commented that "most people will usually prefer a daylit interior to one which is windowless and completely isolated from the outdoor scene... On the other hand, daylight is not regarded as the exclusive source to be used. Its limitations are recognized and although general agreement has not yet been reached on the ways in which daylight and artificial light should be continuously integrated in all types of interiors, nevertheless it has been shown that a combination of artificial light with daylight can provide a solution which is better than that provided by either source alone."

Daylight contributes to the quality of interior lighting by providing a directional component (O'Sullivan, 1973; Lowson, 1970). Because windows are located on the side walls, daylight enters a building horizontally. This horizontal direction to daylight contributes to the "modelling" of objects (Jackson and Holmes, 1973a; Button, 1970). Modelling can increase the apparent detail of an object while improving its appearance (Ne'eman and Longmore, 1973). Thus daylight has a more pleasing and natural character than artificial illumination. Jackson and Holmes (1973b, p. 80) commented that "much of the window's contribution to the built environment is classed as qualitative -- there is a marked difference in the 'feel' of an interior lit from side windows as compared with normal electric lighting.... Furthermore, the short term variations add an extra dimension to the daylit interior and undoubtedly contribute to the avoidance of monotony sometimes found under static installations. It is interesting that attempts to produce this effect in electric lighting seem strangely artificial and almost annoying."

The quality of daylight illumination was considered so important in Britain that a system known as Permanent Supplementary Artificial Lighting Installation (PSALI) was developed. In PSALI, daylight provides most of the illumination which is supplemented by some artificial light (Hopkinson, 1961). PSALI is particularly effective in offices which are too large to be completely daylit, and yet should provide some of the quality of daylight. "Such rooms cannot be well lit to adequate standards of lighting by daylight alone. Nevertheless, it is felt that daylight in all its variety and stimulation must be provided, and must be the dominant feature of the room lighting, rather than it should be shut out by blinds or merely allowed to peep through small view windows. The only way to achieve this end in these circumstances is by the use of permanent supplementary artificial illumination" (Hopkinson and Longmore, 1959, p. 139).

In PSALI, daylight rather than artificial light is considered to be the dominant source of illumination, up to about 40 ft (12.2m) from the window. Beyond this distance in the deep office, daylight "is used as a supplement to the artificial light in order to accentuate the lighting of the interior and particularly to satisfy the subjective demands for variation, interest and visual contact with the outside world" (Ne'eman and Longmore, 1973, p. K-7).

An additional advantage to the use of a system such as PSALI is that daylight can be used near the windows instead of artificial illumination on all but the gloomiest of days. If daylight is used as the sole source of light near the window and as a supplement further away, the energy requirements of artificial lighting can be reduced,

without lessening the quantity of illumination. If the assumptions of PSALI are correct, not only should energy be saved, but the quality of the room lighting should also be more pleasurable.

Although it seems generally accepted that people prefer daylight to artificial lighting, there has been relatively little research into lighting preferences. Most of the statements about lighting preferences are made by illumination engineers, not by the people who use the building. One of the few preference studies was by Wells (1965), who theorized that people could not estimate accurately the relative percentages of both daylight and artificial light in their office. Consequently, Wells asked clerical personnel to estimate the amount of daylight in their offices. As the same time, he questioned them about their desires for both daylight and view.

The results of Wells' study confirmed his hypothesis that people seated at a distance from a window are not able to judge the relative proportions of daylight and artificial light. Subjects were quite accurate at estimating the percentage of daylight up to about 20 ft (6.1m) from the windows. Beyond 20 ft (6.1m), however, they consistently overestimated this percentage. Nevertheless, their belief that daylight is a better illuminant and their desire for a view were not diminished by increasing distance from the window. Wells interpreted these findings as indicating that subjects were not particularly sensitive to the actual environment but rather responded in terms of preconceived attitudes and desires.

Yet, nowhere, in the course of the research, did Wells address the contributions made by daylight to the quality of illumination. Furthermore, his hypothesis about subject overestimation of the proportion of daylight "derived from the experimenter's surprise at the proportion of daylight in the total illumination of the larger office areas when checking the sources of illumination with a light meter. One was surprised at how rapidly this proportion dropped as one moved away from the window" (Wells, 1965, p. 58). Thus, Wells too, was subject to the same illusion as the office personnel. The persistency of this illusion of illumination can extend deep into an office. Subjects may well respond to this as much as to the actual amount of daylight.

Whatever the cause, when subjects have been directly asked about their desire for daylight, they have generally expressed a strong preference for daylight in their offices. For example, Wells (1965) found that 69 percent of his subjects desired daylight; Markus (1967a) noted that 95 percent of his subjects preferred daylight to work by; and Manning (1965) discovered that 65 percent of his subjects wanted daylight. All of these subjects expressed the belief that daylight is superior to artificial illumination.

Sunshine

In addition to the apparently widespread desire for daylight there is another component of external illumination, sunshine, which appears to create a whole host of psychological reactions all of its own. For example, a review of the available literature on sunshine by Hohm and Roessler (1972) revealed a widespread desire for sunshine in residential dwellings.

Unlike daylight, there have been a number of investigations into the desire for sunshine. One such study, done in Holland, by Bitter and van Ierland (1967), surveyed almost a thousand housewives about their opinions of the sunshine, daylight, warmth, and other aspects of their dwellings. Eighty-five to ninety percent of the housewives expressed an overwhelming preference for sunlight, particularly in the living room. The desire for sunshine was so strong that about seventy percent of the subjects preferred a sunny room without a good view to a non-sunny room with a beautiful view. Furthermore, these Dutch subjects were prepared to sacrifice sunshine in the bedrooms and kitchens for sunshine in the living room (where they spent most of their time). In another investigation, Grandjean, Gilgen and Barrier (1973) administered a questionnaire to residential dwellers and measured the amount of sunshine in their apartments. Their survey revealed that sunshine was more important than other aspects of the dwelling (such as noise, illumination, presence of a balcony, or distance to work). When subjects were asked to rate the duration of sunshine in their dwellings, their ratings agreed quite well with the physical measurements. These results were used to set minimum sunshine standards ranging from one to three hours for an entire apartment. The importance of sunshine in housing is reinforced by Hopkinson (1967) who reported an early British survey which indicated that 75 percent of the housewives questioned preferred sunlight in the room in which they were working.

The study of the desire for sunlight has not been restricted to the inhabitants of residential dwellings. Ne'eman and Longmore (1973) administered a questionnaire to the occupants of four different building types: schools, houses, offices and hospitals. The results indicated that preferences for sunshine varied with the kind of environment. Ninety percent of the occupants of residential dwellings, 91 percent of hospital patients, 73 percent of office workers and 42 percent of those in schools wanted some sunshine in their environment. On the other hand 62 percent of the hospital staff, 52 percent of those in schools, 24 percent of office workers, and 4 percent of those in homes considered sunshine to be a nuisance. The differences in preferences may be related to the individual's ability to use shading to control excessive thermal gain and glare (Longmore and Ne'eman, 1973). Ne'eman (1974, p. 162) commented that "the appreciation of sunshine is actually dependent upon the type of building and the kind of activities which the occupants usually perform... the difference in the response to the sun by people performing different activities within the same interior is an important criterion for proper environmental design."

Although all the surveys of human preferences have revealed a general desire for sunshine, there are some problems associated with research based on "expert judgments" and user surveys. Aware of these, Hopkinson (1967) noted some difficulty with obtaining valid data from surveys of user needs and preferences about the visual environment. He claimed that "when people are interviewed for the first time about the sunlight in their building, they find themselves having to answer questions about which they have never previously given any thought, and

as a result, they tend to answer by the easiest way out, that is by saying directly or indirectly that they are content with the way things are" (Hopkinson, 1967, p. 13). For example, Bitter and van Ierland (1961) had found some tendency for the housewives in their survey to prefer the existing situation, particularly in bedrooms and kitchens, though not for their living rooms.

Although Hopkinson's warnings deserve consideration, the evidence for a desire for sunshine is strong. Yet, this desire may be strongest for residents of northern latitudes where the duration of sunshine can be quite limited. The numerous references in the literature to "sunshine deprivation" in northern countries suggests that their inhabitants have a very strong desire for sunshine (Hollister, 1968; Goromosov, 1968; Ne'eman, 1973). On the other hand, observations made in South Africa and Israel suggest that people in these countries tend to avoid sunshine in their buildings because of its excessive heat (Richards, 1967; Morgan, 1967). Thus, the desire for sunshine in buildings is strongest where the duration of sunshine is most limited. The desire for sunshine also appears to be affected by the activity occurring within a building. Ne'eman (1974, p. 163) suggested that "the more confined the activity the more severe the adverse effects of sunshine may be."

Relative Importance of Sunshine and View

If people must choose between sunshine in their building and a good view from it, which would they prefer? As mentioned earlier, Bitter and van Ierland's subjects claimed they preferred sunshine to view if a choice had to be made. In a review of some of the literature on view,

privacy, sunshine and daylight, Brierly (1971, p. 120) disagreed with this finding, and noted that "if the order of precedence of controls is to be related to the satisfaction of people with the environment, it is possible that view would become the significant factor, as there are indications that the view from both living room and kitchen windows, and the appearance of the housing areas are major components of the resident's satisfaction with the environment. The indications are that the other factors, sunshine, daylight and visual privacy, do not correlate highly with the satisfaction scale." Longmore and Ne'eman (1973) concurred with this statement, noting that in their study, sunshine, daylight and privacy were less important determinants of satisfaction than view.

In an assessment of the relative importance of some of the components of the visual environment, Markus and Gray (1973) used a variety of techniques to determine the overall importance of view, sunshine, brightness and privacy. Initially, they conducted a series of pilot studies to develop several rating scales to evaluate satisfaction with windows in residential dwellings in Scotland. Among the techniques used in the pilot studies were open-ended questionnaires, limited rating scales, sentence completion and slide evaluation. The first three approaches were used with residents of different types of urban housing; the latter approach was employed with architecture students.

The findings from the pilot studies indicated that a number of factors determined satisfaction with windows in residential environments. Satisfaction appeared to be related to the amount of greenery and "nature" visible, to the amount and kind of activity occurring, and to the degree of brightness of the visible scene. Dissatisfaction was affected by the number of buildings visible and by infringements upon privacy. Satisfaction with privacy appeared to be related equally to a desire for some contact with neighbors and for some visual privacy. Six psychological scales, relating to general satisfaction, activity, visual privacy, spaciousness, brightness and actual privacy, were developed from the pilot data.

In Markus and Gray's final large-scale study, the data obtained from residents of 450 housing units on six different sites were analyzed in terms of the six scales developed earlier. Markus and Gray confirmed their earlier findings that visual satisfaction was strongly related to the visible extent of grassy area around a house, the size of the garden, the amount of open space, and the distance between houses. Furthermore, brightness, spaciousness, and the amount of sky visible through a window were also deemed important. Surprisingly enough, neither sunlight nor window size correlated with satisfaction, although brightness and spaciousness did.

Control of Daylight and View

In the quest for illumination and view, windows have been made larger and larger. While the view may be better there can be some unpleasant thermal side-effects. With increased size, windows frequently admit more heat, particularly if the building has an unshaded west or

south orientation. Furthermore, this solar heat gain can exert a tremendous strain upon the air conditioning system, resulting in considerable energy waste. As a result, requirements for minimum sunshine and daylight have created another set of problems.

Langdon (1968) and Langdon and Loudon (1970) found that clear, single-glazed windows large enough to meet the British minimum daylight factor on overcast days admitted excessive heat on bright, sunny days. Furthermore, these large windows can result in annoying glare (Hopkinson, 1963; 1972). Problems with the excessive heat and glare led to the relaxation of some overly stringent daylight standards, and the provision of some artificial lighting in the schools (Button, 1970).

Woodford (1973, p. 5) noted that "Provisions for good sunlight and daylight in buildings is important, but not necessarily more important than other requirements -- such as the economic use of urban land, good views from the windows, and quiet rooms -- and may sometimes be difficult to reconcile with these... In short, the aims of planning for sunlight and daylight must be integrated with the aims of planning generally, not pressed too far, not forgotten and not allowed to obscure other aims." Loudon (1968) also recommended that "there is a need for criteria to assess in advance whether a room will get too hot during sunny spells, taking account of all relevant factors such as orientation, ventilation, thermal capacity, shading of windows and so on" (p. 72).

Although reducing window size can control solar heat gain and energy waste, if too small, windows will no longer provide much daylight or a good view. Furthermore, very small windows can create annoying glare spots through contrast with the darker surrounding walls (Hopkinson, 1972). Other techniques that have been used to reduce both solar heat gain and glare, are external and internal shades, blinds, and special glazing. Because little research has been done into user reaction to external or internal shading devices, these will not be discussed further. However, there has been some research into the reaction of building occupants to the special solar glasses that have been developed to reduce glare and thermal problems.

Because the special solar glass is tinted, it will alter and reduce the light transmitted into a room. The two major types of solar glass, solar absorbing and solar reflective, both reduce solar heat gain and glare. Solar absorbing glass is tinted with certain colors which reduce the transmission of the visual spectrum, thus lessening problems of glare while absorbing a certain amount of solar heat. Solar reflective glass, on the other hand, is coated with reflective material so that it can reflect more light than it transmits. Because this glass typically reflects radiant heat, it is more effective than the solar absorbing glass in controlling heat gain through a window.

Cooper, Wiltshire and Warren (1973) and Cooper, Wiltshire and Hardy (1973) investigated the reaction of office personnel to both types of special solar glass. They conducted 3 studies: 1. A limited pilot survey of the occupants of several individual offices to determine the reaction to different types of solar glazing; 2. A small-scale model

study to define the problems associated with solar reflective glass; and 3. A more extensive questionnaire survey of the occupants of 11 office buildings to determine the effects of the glass in the context of the total office environment.

In the first study, a number of small offices were glazed with several types of solar absorbing and solar reflecting glass. Subjects were questioned informally about the glass. Cooper and his associates found that there was little adverse reaction to the different types of solar absorbing glass but quite a lot to two types of solar reflecting glass with light transmissions of 12 and 15 percent. "The occupants of the rooms complained of the depressing visual effect of the external view due to the reduction in luminance, the need to use artificial light during daylight hours in a room with the external wall 60 percent glazed and the fact that the glass became a mirror to the room interior when external illumination levels were low. This effect, which was intermittent in daytime, resulted in peripheral vision distraction to the occupant" (Cooper, Wiltshire and Warren, p. 3).

The unfavorable reaction to the solar reflective glass in the pilot study led Cooper et al. to do a small, scale model investigation of the problems of reflections associated with this glass. In this experiment, a number of views containing different proportions of sky luminance were projected onto a screen at a constant level of illumination. The subject was asked to adjust the level of illumination to determine the point at which the reflections from the glass masked the view. The results indicated that as the ratio between internal and external luminance increased, the reflections masked the view to a greater

extent. These two preliminary studies indicated that two factors would determine the acceptability of solar glass in real office buildings. One was the reduction of the luminance of the external view by the glass. The second was the actual masking of the view by the internal reflections created by the solar reflective glass.

The next step in the investigation was to determine whether these two factors would apply in actual office buildings. Cooper and his associates administered a questionnaire to 902 persons in 11 office buildings with window sizes ranging from 30 to 95 percent of the external wall. Their questionnaire covered all portions of the office environment, in an attempt to avoid paying undue attention to the windows.

Contrary to expectations, the results revealed that the type of glass had no effect upon the judgment of the pleasantness or brightness of the view. Furthermore, there appeared to be no effect upon the range of colors perceived in the office. In addition, the problems associated with the reflective glass were not nearly so important as had been expected from the pilot work.

The authors concluded that "tinted glass has little or no effect on the visual environment for office workers. If the view outside is sufficiently interesting, the appearance of the window glass itself is not noticed. It proved impossible to distinguish any significant effects due to the colour or transmittance of the glass. The reflectance of the glass did however have a small adverse effect on the pleasantness of the view... It is of interest that only in buildings where more than one type of glazing had been used were there specific

complaints attributable to the glass. This was probably because under these conditions the presence of the glass could be easily detected" (Cooper, Wiltshire and Hardy, 1973, p. 12).

The reasons for the discrepancies between the results of the preliminary studies and of the large-scale study are not entirely clear. The authors suggested that the subjects were more conscious of the reflections from the glass in the pilot study than in a real office situation. They claimed that "it is now clear that these must have been largely due to the situation itself, where the subjects had nothing to do but look at the view through the window. In the real situation studied by the survey, although reflections still occur, they are not sufficiently important to office workers for many of them to have an opinion on the subject." They did mention that there were some complaints from an office where a plastic film had been added to an antisun glass. Here 20 percent of those affected disliked the glass because it cut down the light too much on dull days.

A problem that is not discussed by Cooper and his associates is the fact that the glass in most of the buildings transmitted more than 50 percent of the incident light. Although the glass that had caused problems in the preliminary study had transmitted only 12-15 percent of the light, in the latter study only one building had glass with this transmittance. Yet, the preliminary data had indicated that this lower transmission glass is the most disliked, particularly on gloomy, overcast days. Because the glass that is most effective in reducing energy consumption is of this low transmittance, reaction to this glass in real office buildings should be investigated further.

Photobiology

In addition to reducing light transmission through a window, the special solar glasses alter the spectral quality of the light that is transmitted. Furthermore, the spectral quality of artificial illumination is usually different from that of daylight, particularly at the short wavelength end. The effect of these differences in spectral quality upon normal biological functions is not known. It is becoming increasingly clear, however, that "environmental lighting exerts important effects upon human health and productivity, far beyond its requirements for vision" (Wurtman, 1973, p. 79). Such effects include vitamin D synthesis and maintenance of normal biological rhythms (Wurtman, 1967; 1968).

The differences in spectral quality between natural and artificial lighting are probably not critical if people can have access to sunshine and natural daylight as well. Yet, during the winter months, the daylight hours are so short that many people, particularly those who must work inside, are not exposed to sunshine and daylight for long periods of time. As a result, they are deprived of some ultraviolet and other short wavelength light. While excessive amounts of such light can be carcinogenic, moderate amounts appear to be beneficial (Smith, 1973; Logan, 1968). In fact, the Russians have insisted upon the inclusion of trace amounts of ultraviolet light in the lighting systems for factories and mines (Goromosov, 1968). They claim lack of ultraviolet lowers resistance to disease, reduces vitality, and causes the worker to tire more quickly (Hollister, 1968; Leposky, 1974).

Research into the effects of illumination upon living organisms suggests that "It seems reasonable that the light sources to which we expose people should not deviate markedly from the lighting environment under which people evolved in nature. The fragmentary data now available suggests that working under such "natural" conditions significantly decreases visual fatigue and may also increase productivity" (Wurtman, 1973, p. 81). Ott (1965, 1973) has demonstrated numerous detrimental occurrences in growth and reproduction when animals and plants are raised in an environment whose illumination spectrum deviates markedly from the normal. It is clear that "light is a true environmental factor as much as or even more than air, water or temperature. Attempts to change it from the natural, either compositionally or to drastically modify the portion delivered to a living system can logically be expected to have some effect" (Thorington, Cunningham and Parascandola, 1971, p. 246).

The study of photobiology indicates that people have physiological as well as psychological requirements for illumination. Because this research is relatively recent, it is difficult to conclude that requirements for illumination of a particular spectral composition exist, although this possibility should not be ignored.

Privacy

In addition to daylight, sunshine, and view another parameter that must be considered in window design is that of privacy. Positioning a window so that it is easy for people to look in and observe the behavior of the inhabitants is undesirable. Furthermore, a window which affords

an expansive view can decrease privacy to an unacceptable level so that people might prefer a smaller window with a less extensive view but more privacy. Thus, in some situations, such as ground level rooms, the desire for privacy may overcome the desire for a view. Nevertheless, Markus and Gray (1973) noted some conflicting desires even in this situation. On one hand, the residents of the dwellings being studied wanted privacy from prying neighbors, but on the other hand, they wanted contact with other people and expressed a dislike of the isolation that can accompany too much privacy (Markus and Gray, 1973). These conflicting desires would appear to have opposing influences upon window design. Window size is not the only means of controlling privacy, however, since curtains, blinds, and shades are also effective. Because these devices are directly under an individual's control, they are probably the best means for affording both privacy and view. Despite the importance of this topic, there is very little research on the effect of window size or position upon the desire for privacy.

Spaciousness

A number of investigators have suggested that another important quality associated with windows can be identified as spaciousness. The results of the next four studies indicate that the presence of a window can increase the apparent size of a room.

Mercer (1971) studied the effect of windows upon perceived size by asking students of psychology and architecture to make six estimations of size in each of three rooms. These students judged the size of their head, the width of their shoulders, and the length (imagined) of twelve inches and six inches, in the presence and absence of a standard for comparison. These estimates were made in a variety of situations: a small room with a window; a small room without a window; and a large room (6.2 times the volume of the small room) without a window.

Mercer found that the presence of a window did not affect a person's judgment of actual length, but did increase slightly his estimate of imagined length. The presence of a window had the greatest impact upon a person's perception of his own size. Mercer's subjects judged themselves to be larger in a room with a window than in one without, even when this was substantially larger than the room with the window. "In other words, the window affects most the person's perception of himself -- it makes him 'feel' better, as manifest in his increased body boundary" (Mercer, 1971, p. 54).

The second set of investigations, by Collingro and Roessler (1972), took a slightly different course. Using a questionnaire, they investigated the effect of variables such as window size and illumination level upon feelings of enclosure. Subjects reported extensive feelings of enclosure and restraint with very small, or no windows, but not with larger ones. The room with smaller windows, however, was considered to have more privacy. Although increasing the level of artificial illumination appeared to overcome some of the feelings of enclosure and restraint, Collingro and Roessler concluded that this approach was not very successful for windowless rooms or rooms with tiny windows.

In still another type of approach Inui and Miyata (1973) examined the effect of a window upon a subjective variable which they termed "spaciousness". Defining "spaciousness" as the feeling of openness or enclosure produced by an interior, they claimed that it is primarily determined by a person's visual perception of a space. As they have defined it, spaciousness is a measure of the perceived expanse of a space (unrelated to pleasure or acceptability).

Inui and Miyata (1973) employed 10 subjects who evaluated several models (1/20, 1/10 and 1/5 scale). The subjects' evaluations were used to scale "spaciousness" psychophysically so that the impact of such variables as daylight, sunlight, window size and room volume upon perceived spaciousness could be assessed.

The results from Inui and Miyata's study revealed that window size had the greatest effect upon perceived spaciousness. Moreover, this effect appeared to be increased for a window at eye level. Other factors which were found to increase the spaciousness of a room were increased sky luminance, and room volume. The judgments of spaciousness were not systematically affected by differences in the size of the various models employed.

Inui and Miyata also used the same procedure to assess the perceived spaciousness of actual rooms. Forty-three offices, interior rooms and conference rooms were studied with 8 subjects at the University of Tokyo. It was found that the same factors that had been important in the scale-model rooms also affected perceived spaciousness in these full-scale rooms.

The findings by Inui and Miyata described thus far relate only to spaciousness, not to any feelings of pleasure or acceptability that might be associated with it. Inui and Miyata were also concerned, however, about positive emotional reactions created by a "spacious" interior. In pursuing this topic, they assessed the effect of parameters such as room volume, window size, and sky luminance upon "just acceptable spaciousness".

The results of Inui and Miyata's study of the emotional attributes associated with "spaciousness" indicated that subjects were able to place "just acceptable spaciousness" on the psychophysical scale of spaciousness. The "just acceptable spaciousness" of a room was determined by its volume and by the presence of windows. Thus, the greater the volume or the larger the windows, the more acceptable the spaciousness was judged. Because subjects were able to use the concepts of "spaciousness" and "just acceptable spaciousness" with a great deal of consistency and reliability, Inui and Miyata advocated the application of these concepts to the design of building interiors.

In another investigation Imamoglu and Markus (1973) defined spaciousness as a feeling resulting from the visual perception of an interior area. They examined the effects of window size, room shape, and window location upon spaciousness with a large number of subjects (120), using both full-and small-scale (1/10) models. Unlike Inui and Miyata, who had had their subjects rate the spaciousness of different rooms, Imamoglu and Markus asked subjects to adjust each of 2 adjustable rectangular models to be equal to a fixed square model in spaciousness. The effects of window size, room proportion and length of window wall upon spaciousness were assessed by adjusting a model.

Imamoglu and Markus found no correlation between window size or room proportion and spaciousness. These results disagree with those of Collingro and Roessler (1972) and Inui and Miyata (1973), who had found window size to be directly related to perceived spaciousness. On the other hand, Imamoglu and Markus did find a very significant interaction between window size, room properties and spaciousness, so that several small windows gave greater feeling of spaciousness to a square-like room than did large continuous windows. In contrast, continuous windows gave greater feelings of spaciousness in a rectangular room. No matter what the room proportions were, the rooms were perceived as more spacious when the windows were on a short wall than on a long one. These findings indicate that square-like rooms appear more spacious with a continuous window on the short wall.

The results of these two studies (Imamoglu and Markus, 1973; and Inui and Miyata, 1973) indicate that subjects can define and use a concept termed "spaciousness" fairly consistently. This concept is related to, but not entirely dependent upon, the presence of windows within a room. Thus, a large windowless room, with a high ceiling, large volume, and bright lighting could be judged as spacious, although it probably would be judged as more spacious if a window were present.

The various studies on spaciousness indicate that windows can add an important psychological dimension to a room, so that the mere presence of a window will increase its apparent size. Furthermore, windows can reduce feelings of enclosure and restriction. Yet, very large windows do not appear to be necessary for this purpose. Instead, moderate-size windows can be effective if placed at eye level on the

short side of the room. If window size is reduced too far, however, the room will lose this quality of apparent spaciousness. These findings indicate that the presence of windows can alter the quality of a room in a fashion almost unrelated to external factors such as view or sunshine.

Summary

In Section II, numerous functions and benefits provided by windows were identified. Perhaps the most highly valued of these is the provision of a view, or some contact with the outside world. The desirability of a view appears to be related to the amount of information available and to the extent of sky, horizon, and ground visible. A view seen through a window seems to be able to satisfy both esthetic and intellectual demands. Although a view out is generally regarded as desirable, in some restricted and monotonous situations, it becomes almost a necessity.

In addition to view, there are several other benefits provided by windows that appear to be essential in governing satisfaction with them. Although there are still questions about the physiological requirements for daylight and sunshine, the importance of these for the psychological well-being of a building's inhabitants should not be underestimated. Daylight and sunshine contribute a highly dynamic character to the internal environment of a room. They introduce change and variety into an otherwise static atmosphere. The addition of dynamic qualities through the provision of view, daylight and sunshine appears to be one of the most vital functions performed by a

window. In addition, the presence of windows appears to make a room seem more spacious, so that a small, cramped room is perceived as larger.

While there are some disadvantages to windows such as undesirable heat gain, glare, and lack of privacy, the advantages of view, sunshine, daylight and spaciousness appear to outweigh them substantially. Certainly, windows appear to afford a great deal of pleasure for the residents of various kinds of buildings.

CONCLUSIONS

Although the research reviewed in this paper has emphasized the desirability of windows for people in buildings, it is difficult to draw substantive conclusions beyond this. Final conclusions are limited by the paucity of research in most of the areas reviewed. For example, although the conclusion that windowless rooms are not particularly desirable appears legitimate, this opinion is not based upon a large number of investigations. In fact, the best evidence for this dislike comes from one study of windowless offices and one of windowless intensive care units. Much, though not all, of the evidence from the windowless classroom studies is inconclusive, or inadequate, while that from windowless factories is circumstantial, based on hearsay, rather than research. As a result, only tentative conclusions can be drawn about the qualities of windowless spaces that make them somewhat less than desirable. Further investigation is needed to determine if dislike of a windowless space is in fact determined by the kind of task, the amount of personal interaction, the size of the space, and the variety of activity. Once questions such as these have been researched, then

better decisions can be made about the design for spaces which must be windowless, so that human needs can be satisfied rather than sacrificed.

While the research into the reaction to windowless places suffers from a lack of specificity, that into the reaction to windows suffers from a lack of synthesis. Rarely has the overall impact of a window been investigated. Although much research has been done into preselected aspects such as view, daylight, or spaciousness, it is impossible to determine if these are all the benefits that set a windowless space apart from one with windows. Furthermore, almost all the research into the various functions of windows has been done in Great Britain and Northern Europe, rather than the United States. It is conceivable that cultural and climatic variations might cause substantial differences in the desirability of such aspects as sunshine and privacy. The investigations into reaction to windows suggest some of the benefits, but do not provide any final answers about why windows are desirable.

Because of the numerous areas in which further research should be done, it is difficult to make any recommendations about the best window design for satisfying both human and energy requirements. While there are some situations in which the elimination of windows may be acceptable, because human needs are met by the situation itself, this is certainly not true for the majority of buildings. Furthermore, while reduction in window size may be appropriate for some buildings, it is difficult to make any recommendations about the optimal size for all buildings. Although almost all of the British studies on minimum window size point to a size of about 20 to 30 percent of the window wall for office buildings, these recommendations have never been researched

with people in actual buildings. The question of "minimum acceptable window size" has not been investigated for other types of buildings, with the scale model or any other sort of approach. Even in the limited number of studies on window size in offices, there are conflicts in the findings about the best shape and position of the reduced window area. The reaction to other means of reducing energy loss due to windows, such as double and triple glazing, shading devices, and special types of glass has not been explored in detail. The one study on attitudes toward special solar glass found many discrepancies between the scale-model studies and the actual office studies that are difficult to explain. Discussion of these various limitations and discrepancies can provide some understanding of the problems involved in specifying design solutions for both energy requirements and human demands.

It seems clear that there is no single solution, such as windowless buildings or minimal windows, for reducing energy consumption due to windows, because human requirements cannot as yet be specified fully. It is evident, however, that windows do perform desirable functions for people in buildings that should not be overlooked in the design of energy efficient buildings.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

An understanding of human requirements for windows in buildings can be developed through a survey of the literature on the reaction to environments with and without windows. Evaluation of the response to a variety of windowless situations reveals that although the attitudes toward a windowless space are often somewhat unfavorable, the most adverse reaction occurs in a small, restricted and essentially static environment. This suggests that one function performed by a window is the addition of a dynamic, active quality to an interior environment. Consideration of the response to the actual presence of windows indicates that another essential function of a window is the provision of a view of the external world. Although almost any view is acceptable, there is some evidence that views with a high information content are preferable. In addition, windows admit illumination, in the form of daylight and sunshine which furnish a dynamic, changing character to a room. Yet, the functions of windows extend beyond view and illumination to an enhancement of the basic character of a room, such that the mere presence of a window may cause a room to appear more spacious. Finally, the optimum size and shape of a window for fulfilling these various functions is discussed.

17. KEY WORDS *(six to twelve entries, alphabetical order, capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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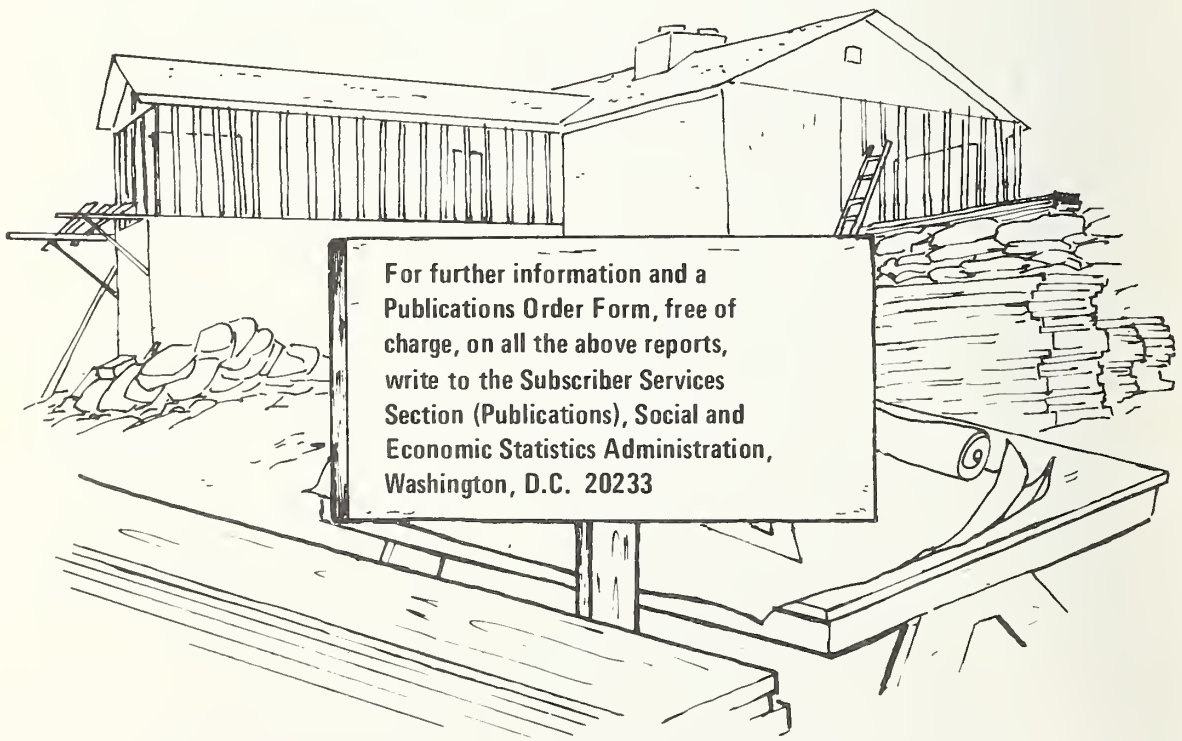

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